Need for measurement in physics

- To understand any phenomenon in physics we have to perform experiments.
- Experiments require measurements, and we measure several physical properties like length, mass, time, temperature, pressure etc.
- Experimental verification of laws & theories also needs measurement of physical properties.

Types of physical quantities

1. Fundamental quantities:

The physical quantities which do not depend on any other physical quantities for their measurements are known as fundamental quantities.

Examples:

- Mass
- Length
- Time
- Temperature

Types of physical quantities

2. Derived quantities:

The physical quantities which depend on one or more fundamental quantities for their measurements are known as derived quantities.

Examples:

- Area
- Volume
- Speed
- Force

Units for measurement

The standard used for the measurement of a physical quantity is called a unit.

Examples:

- metre, foot, inch for length
- kilogram, pound for mass
- second, minute, hour for time
- fahrenheit, kelvin for temperature

International System of units (SI)

- In 1971, General Conference on Weight and Measures held its meeting and decided a system of units for international usage.
- This system is called international system of units and abbreviated as SI from its French name.
- The SI unit consists of seven fundamental units and two supplementary units.

Dimensions of a physical quantity

The powers of fundamental quantities in a derived quantity are called dimensions of that quantity.

Dimensions of a physical quantity

Example:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$= \frac{\text{Mass}}{\text{length} \times \text{breath} \times \text{height}}$$

$$[\text{Density}] = \frac{[\text{M}]}{[\text{L}] \times [\text{L}] \times [\text{L}]} = \frac{[\text{M}]}{[\text{L}^3]} = [\text{ML}^{-3}]$$

Hence the dimensions of density are 1 in mass and -3 in length.

To check the correctness of equation

Consider the equation of displacement,

$$\Delta x = v_i t + \frac{1}{2} a\, t^2$$

By writing the dimensions we get,

$$\Delta x = \text{displacement} = [L]$$

$$v_i t = \text{velocity} \times \text{time} = \frac{\text{length}}{\text{time}} \times \text{time} = [L]$$

$$at^2 = \text{acceleration} \times \text{time}^2 = \frac{\text{length}}{\text{time}^2} \times \text{time}^2 = [L]$$

The dimensions of each term are same, hence the equation is dimensionally correct.

To convert units

Let us convert newton (SI unit of force) into dyne (CGS unit of force).

The dimesions of force are = $[\mathrm{LMT^{-2}}]$

So, $$1\ \text{newton} = (1\ \text{m})(1\ \text{kg})(1\ \text{s})^{-2}$$

and, $$1\ \text{dyne} = (1\ \text{cm})(1\ \text{g})(1\ \text{s})^{-2}$$

Thus, $$\frac{1\ \text{newton}}{1\ \text{dyne}} = \left(\frac{1\ \text{m}}{1\ \text{cm}}\right)\left(\frac{1\ \text{kg}}{1\ \text{g}}\right)\left(\frac{1\ \text{s}}{1\ \text{s}}\right)^{-2} = \left(\frac{100\ \text{cm}}{1\ \text{cm}}\right)\left(\frac{1000\ \text{g}}{1\ \text{g}}\right)\left(\frac{1\ \text{s}}{1\ \text{s}}\right)^{-2}$$

$$= 100 \times 1000 = 10^5$$

Therefore, $1\ \text{newton} = 10^5\ \text{dyne}$

To derive a formula

The time period 'T' of oscillation of a simple pendulum depends on length 'l' and acceleration due to gravity 'g'.

Let us assume that,

$$T \propto l^a g^b \qquad \text{or} \qquad T = K\, l^a g^b$$

K = constant which is dimensionless

Dimensions of $T = [L^0M^0T^1]$

Dimensions of $l = [L^1M^0T^0]$

Dimensions of $g = [L^1M^0T^{-2}]$

Thus, $[L^0M^0T^1] = K\,[L^1M^0T^0]^a\,[L^1M^0T^{-2}]^b$

$$= K\,[L^aM^0T^0]\,[L^bM^0T^{-2b}]$$

$$[L^0M^0T^1] = K\,[L^{a+b}M^0T^{-2b}]$$

$$a + b = 0 \qquad \& \qquad -2b = 1$$

$$\therefore \quad b = -\frac{1}{2} \qquad \& \qquad a = \frac{1}{2}$$

$$T = K\, l^{1/2} g^{-1/2}$$

$$\therefore \qquad T = K\sqrt{\frac{l}{g}}$$

Need for measurement in physics

- To understand any phenomenon in physics we have to perform experiments.
- Experiments require measurements, and we measure several physical properties like length, mass, time, temperature, pressure etc.
- Experimental verification of laws & theories also needs measurement of physical properties.

2. Gross errors

These errors are caused by mistake in using instruments, recording data and calculating results.

Example:

a. A person may read a pressure gauge indicating 1.01 Pa as 1.10 Pa.

b. By mistake a person make use of an ordinary electronic scale having poor sensitivity to measure very low masses.

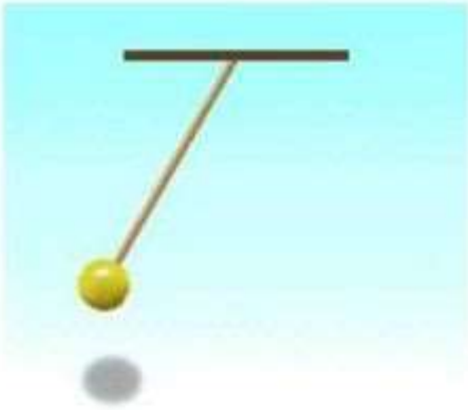
Careful reading and recording of the data can reduce the gross errors to a great extent.

3. Random errors

- These errors are due to unknown causes and are sometimes termed as chance errors.
- Due to unknown causes, they cannot be eliminated.
- They can only be reduced and the error can be estimated by using some statistical operations.

Error analysis

For example, suppose you measure the oscillation period of a pendulum with a stopwatch five times.



Trial no (i)	1	2	3	4	5
Measured value (X_i)	3.9	3.5	3.6	3.7	3.5

Mean value

The average of all the five readings gives the most probable value for time period.

$$\bar{X} = \frac{1}{n} \sum X_i$$

$$\bar{X} = \frac{3.9 + 3.5 + 3.6 + 3.7 + 3.5}{5} = \frac{18.2}{5}$$

$$\bar{X} = 3.64 = 3.6$$

Absolute error

The magnitude of the difference between mean value and each individual value is called absolute error.

$$\Delta X_i = |\bar{X} - X_i|$$

The absolute error in each individual reading:

X_i	3.9	3.5	3.6	3.7	3.5
ΔX_i	0.3	0.1	0	0.1	0.1

Mean absolute error

The arithmetic mean of all the absolute errors is called mean absolute error.

$$\Delta\bar{X} = \frac{1}{n}\sum \Delta X_i$$

$$\Delta\bar{X} = \frac{0.3 + 0.1 + 0 + 0.1 + 0.1}{5} = \frac{0.6}{5}$$

$$\Delta\bar{X} = 0.12 = 0.1$$

Reporting of result

- The most common way adopted by scientist and engineers to report a result is:

$$\text{Result} = \text{best estimate} \pm \text{error}$$

- It represent a range of values and from that we expect a true value fall within.
- Thus, the period of oscillation is likely to be within (3.6 ± 0.1) s.

Relative error

The relative error is defined as the ratio of the mean absolute error to the mean value.

$$\text{relative error} = \Delta\bar{X} \,/\, \bar{X}$$

$$\Delta\bar{X} \,/\, \bar{X} = \frac{0.1}{3.6} = 0.0277$$

$$\Delta\bar{X} \,/\, \bar{X} = 0.028$$

1. **Light year is a unit of …**
   1)Time 2)Mass
   3)Distance 4)Energy
2. **Unit of power is**
   1)*Kilowatt* 2) *Kilowatt-hour*
   3)*Dyne* 4)*Joule*
3. **Density of wood is** $0.5 gm/cc$ **in the CGS system of units. The corresponding value in SI units is…**
   1) 500 2) 5
   3) 0.5 4) 5000
4. **Which of the following is a derived unit …**
   1) Unit of mass 2) Unit of length
   3) Unit of time 4) Unit of volume
5. **Dimensional formula** ML^2T^{-3} **represents…**
   1)Force 2)Power
   3)Energy 4)Work
6. **The dimensions of universal gravitational constant are …**
   1) $M^{-2}L^2T^{-2}$ 2) $M^{-1}L^3T^{-2}$
   3) $ML^{-1}T^{-2}$ 4) ML^2T^{-2}
7. **The dimensions of power are …**
   1) $M^1L^2T^{-3}$ 2) $M^2L^1T^{-2}$
   3) $M^1L^2T^{-1}$ 4) $M^1L^1T^{-2}$
8 **The dimensional formula for impulse is …**
   (a) MLT^{-2} (b) MLT^{-1}
   c) ML^2T^{-1} (d) M^2LT^{-1}
9. **The velocity of a freely falling body changes as** $g^p h^q$ **where *g* is acceleration due to gravity and** h **is the height. The values of** p **and** q **are …**
   1) $1, \frac{1}{2}$ 2) $\frac{1}{2}, \frac{1}{2}$
   3) $\frac{1}{2}, 1$ 4) $1, 1$
10. **Dimensions of frequency are …**
   1) $M^0L^{-1}T^0$ 2) $M^0L^0T^{-1}$
   3) M^0L^0T 4) MT^{-2}
11. **The dimensions of pressure are …**
   1) MLT^{-2} 2) $ML^{-2}T^2$
   3) $ML^{-1}T^{-2}$ 4) MLT^2
12. **Dimensions of kinetic energy are …**
   1) ML^2T^{-2} 2) M^2LT^{-1}
   3) ML^2T^{-1} 4) ML^3T^{-1}
13. **Dimensions of potential energy are …**
   1) MLT^{-1} 2) ML^2T^{-2}
   3) $ML^{-1}T^{-2}$ 4) $ML^{-1}T^{-1}$
14. **Density of a liquid in CGS system is 0.625** g/cm^3 **. What is its magnitude in SI system …**
   1) 0.625 2) 0.0625
   3) 0.00625 4) 625
15. **The percentage errors in the measurement of mass and speed are 2% and 3% respectively. How much will be the maximum error in the estimation of the kinetic energy obtained by measuring mass and speed …**
   1) 11% 2) 8%
   3) 5% 4) 1%
16. **What is the number of significant figures in** $\mathbf{0.310 \times 10^3}$ **…**
   1) 2 2) 3
   3) 4 4) 6
17. **Error in the measurement of radius of a sphere is 1%. The error in the calculated value of its volume is …**
   1) 1% 2) 3%
   3) 5% 4) 7%
18. **The radius of a sphere is (5.3 ± 0.1) *cm*. The percentage error in its volume is ..**
   1) $\frac{0.1}{5.3} \times 100$ 2) $3 \times \frac{0.1}{5.3} \times 100$
   3) $\frac{0.1 \times 100}{3.53}$ 4) $3 + \frac{0.1}{5.3} \times 100$
19. **The period of oscillation of a simple pendulum in the experiment is recorded as 2.63 s, 2.56 s, 2.42 s, 2.71 s and 2.80 s respectively. The average absolute error is …**
   1) 0.1 s 2) 0.11 s
   3) 0.01 s 4) 1.0 s
20. **According to *Joule*'s law of heating, heat produced** $H = I^2$ ***Rt*, where *I* is current, *R*is resistance and *t* is time. If the errors in the measurement of *I*, *R* and *t* are 3%, 4% and 6% respectively then error in the measurement of *H* is …**
   1) $\pm 17\%$ 2) $\pm 16\%$
   3) $\pm 19\%$ 4) $\pm 25\%$

21. If there is a positive error of 50% in the measurement of velocity of a body, then the error in the measurement of kinetic energy is …

1) 25% 2) 50%
3) 100% 4) 125%

22. The number of significant figures in all the given numbers 25.12, 2009, 4.156 and 1.217×10^{-4} is ...

1) 1 2) 2
3) 3 4) 4

23. Error caused due to minute change in experimental condition is …

1) random error 2) systematic error
3) instrumental error 4) absolute error

24. Mass of electron is 9.11 x 10^{-31} kg, its order of magnitude is….

1)-28 2) -30
3) -31 4) -32

25. Which of the following is not a fundamental quantity …

1) thermodynamic temperature 2) force
3) luminous intensity 4)amount of substance

26. Which of the following is a derived unit?

1) Newton 2) Joule
3) Volt 4) all of this

27. Ratio of mean absolute error to true value is ..

1) mean error 2) relative error
3) absolute error 4)systematic error

28. Physical quantity which do not depend on other quantities for their measurements are Called as…

1) fundamental quantities 2) derived quantities
3) system of units 4) SI units

29. Accuracy of the measurement is determined by

1) absolute error 2) percentage error
3) instrumental error 4) mean value

30. The length, breadth and thickness of a block are given by $l = 12\ cm, b = 6\ cm$ and $t = 2.45\ cm$ The volume of the block according to the idea of significant figures should be …

1) $1 \times 10^2\ cm^3$ 2) $2 \times 10^2\ cm^3$
3) $1.763 \times 10^2 cm^3$ 4) 2.5 x $1o^3$ cm^3

31. Position of a body with acceleration '*a*' is given by $x = Ka^m t^n$, here *t* is time. Find dimension of *m* and *n*.

1) $m = 1$, $n = 1$ 2) $m = 1, n = 2$
3) $m = 2, n = 1$ 4) $m = 2, n = 2$

32. The pressure on a square plate is measured by measuring the force on the plate and the length of the sides of the plate. If the maximum error in the measurement of force and length are respectively 4% and 2%, The maximumerror in the measurement of pressure is

1) 1% 2) 2%
3) 6% 4) 8%

33. The surface tension of a liquid is $70\ dyne\ /\ cm$. In MKS system its value is

1) $70\ N/m$ 2) $7 \times 10^{-2}\ N/m$
3) $7 \times 10^3\ N/m$ 4) $7 \times 10^2\ N/m$

34. Which of the following pairs of physical quantities has the same dimensions …

1) Work and power 2) Momentum and energy
3) Force and power 4) Work and energy

35. Which of the following quantities has the same dimensions as that of energy …

1) Power 2) Force
3) Momentum 4) Work

36) Which of the following is dimensionally correct?

1) pressure – energy per unit area
2) pressure = enersy per unit volume
3) pressure = force per unit volume
4) pressure = momentum per unit volume per unit time

37) The units of length, velocity and force are doubled which of the following is the correct change in the other units ?

1) unit of time is doubled
2) unit of mass id doubled
3) unit of momentum is doubled
4) unit of energy is doubled

38) A force is given by F = at + bt², where t is time the dimensions of a & b are …

1) $[M^1L^1T^{-4}]$ and $[M^1L^1T^1]$
2) $[M^1L^1T^{-1}]$ and $[M^1L^1T^0]$
3) $[M^1L^1T^{-3}]$ and $[M^1L^1T^{-4}]$
4) $[M^1L^1T^{-3}]$ and $[M^1L^1T^1]$

39) In the SI uit, the unit of temperature is …

1) degree centigrade 2) Kelvin
3) degree Celsius 4) degree Fahrenheit

40) The dimension's of impulse are equal to that of

1) force 2) linear momentum
3) pressure 4) angular momentum

41) The number of significant figures in … 11.118 x 10^{-6}V is

1) 3 2) 4
3) 5 4) 6

42) What is the number of significant figure in (3.20 + 4.807) x 10^5 …

1) 5 2) 4
3) 3 4)2

43) The radius of a ball is (5.2 $\pm$ 0.2) cm. The percentage error in the volume of the ball is approximately …

1) 11 % 2) 4%
3) 7 % 4) 9 %

44) Which of the following is NOT a character ristic of good unit ?

1) It is invariable 2) It is reproducible
3) It is perishable 4) It is easily available

45) Out of the following units, which is NOT a fundamental unit ?

1) newton 2) second

3) pound 4) kilogram

46) An atomic clock makes use of …

1) cesium 133 atom 2) cesium 132 atom

3) cesium 123 atom 4) cesium 131 atom

47) The radius of the earth is 6400 km, the order of magnitude is …

1) 10^2 m 2) 10^3m

3) 10^4 m 4) 10^7m

48) The number of significant figures in 50.00 is …

1) 1 2) 2

3) 3 4) 4

49) The percentage error in the measurement of length and time is 2% and 1% respectively the percentage error in the measurement of 'g' is ..

1) 2 % 2) 3%

3) 6% 4) 4%

50) The number of significant figures in all the given number 25, 2.9, 4.0 and 1.2 x 10^{-4} is …

1) 1 2) 2

3) 3 4) 4

50) The number of significant figures in all the given number 25.12, 2009, 4.156 and 1.217 x 10^{-4} is …

1) 1 2) 2

3) 3 4) 4